# CHAPTER 1
# Introduction

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Twenty years ago, offshore aquaculture – fish and shellfish farming in U.S. federal waters – was an emerging technology with tremendous potential. The United States and other countries were at the forefront of an engineering and technology revolution, much like the old race to the moon. Bit by bit, scientists, engineers, and researchers began to figure out the "how" for this type of aquaculture. They developed dependable cage systems, remote feeders, monitoring systems, and broodstock for species that would thrive in the open ocean environment. Every success fueled more interest. The potential for this type of seafood production was obvious – so were the challenges. Could this type of aquaculture be brought online safely as a way to complement wild harvest? Would it be economically viable? What about license to operate?

Today, aquaculture in federal waters is among the most talked-about technologies associated with the future of seafood production in the United States. This recent wave of interest in the offshore has strong roots in Chapter 24 of the U.S. Commission on Ocean Policy's September 2004 report to Congress, *An Ocean Blueprint for the 21st Century*. In its report, the Commission recommended that the National Oceanic and Atmospheric Administration (NOAA) develop a comprehensive, environmentally sound permitting and regulatory program for marine aquaculture.[1]

In December 2004, the Administration responded to Commission recommendations with the *President's Ocean Action Plan*. That plan specifically called for national legislation to allow aquaculture in U.S. federal waters. The Administration's legislative proposal to establish a regulatory framework was submitted to Congress in 2005 and again in 2007. The latter proposal also calls for an expanded research program for all of U.S. marine aquaculture.

The introduction of national legislation for marine aquaculture garnered attention in the media and spawned a useful and ongoing national debate about the role of domestic aquaculture in America's seafood supply. That debate centers around a host of marine management, economic, environmental, conservation, health, social, and regulatory issues. It also includes the eventual design of aquaculture regulations for federal waters and associated federal programs. As the agency at the center of the debate, and the one that would likely be tasked with developing and implementing any new federal regulations, NOAA commissioned a study group composed of fisheries resource economists and business experts to address key economic issues associated with offshore marine aquaculture. That effort resulted in this report, *Offshore Aquaculture in the United States: Economic Considerations, Implications & Opportunities.*

[1] Others making similar recommendations included an ad-hoc panel of the American Fisheries Society (Stickney et al. 2006), and the report of the Marine Aquaculture Task Force convened by the Pew Charitable Trusts and the Woods Hole Oceanographic Institute (Marine Aquaculture Task Force 2007).

Coordinated by the NOAA Aquaculture Program, the study group, which includes some of the leading natural resource and fisheries economists in the United States, was asked to examine:

- Trends and factors shaping aquaculture today;
- Forces that will drive it in the future;
- Inputs and outputs necessary to sustain its growth;
- Economic consequences of offshore aquaculture development in the United States; and
- Benefits and costs of such a domestic industry to the nation.

Specifically, the study considers:

- The effect on U.S. offshore aquaculture of global and national trends in seafood supply and demand and other factors that affect market prices, such as cost of feed and technology, social factors, government regulations, and access to sites.
- Useful models from other food segments of the U.S. economy, such as the catfish and poultry industries.
- Interactions between aquaculture and wild harvest fisheries.
- Economic analyses from the broadest to the narrowest scale.

The study also considers the broad, long-term implications of an established domestic offshore aquaculture industry in the United States and the role such an industry might play in helping to meet global demand for seafood, alternative energy, and other sustainable uses of the ocean. It is important to note that much of the analysis in this study, although limited to offshore aquaculture, applies to all U.S. aquaculture.

**Study Caveats**

Several caveats should be noted up front:

1. Each chapter represents the efforts and views of its author(s) and not necessarily the views of other authors or of NOAA.

2. This study – as well as proposed offshore aquaculture legislation and NOAA's Aquaculture Program – should be understood within the context of a broader federal initiative to address all aspects of marine aquaculture. In addition to offshore aquaculture, this broad federal initiative includes coastal shellfish farming, on-shore production methods, and hatcheries to produce stock for private fish and shellfish farms and for marine enhancement purposes.

3. Environmental concerns about all forms of aquaculture are the subject of much debate and widely differing views. And although it was not the purpose of this study to debate these issues, the links between environment and economics are discussed by several of the authors.

4. The study has specific geographical boundaries. Its focus concerns the potential of marine aquaculture in open ocean or offshore locations. It is necessary also to define the term "offshore," because the jurisdiction of U.S. marine waters is unique. U.S. federal waters, also known as the Exclusive Economic Zone (EEZ), are the marine waters beyond the jurisdiction of

coastal states, out to a distance of 200 miles. In most cases, the regulatory control of the states extends to 3 miles offshore, but two states, Florida and Texas, claim jurisdiction out to 9 miles. For marine aquaculture technology, separation between federal and state waters is not important. The complication arises with how such waters are regulated. Under current U.S. law, aquaculture ventures may obtain a permit to operate in most state waters. The five offshore commercial operations and research projects in the United States – in Hawaii, Puerto Rico, California, and New Hampshire – are in state waters, in locations exposed to open ocean or offshore conditions. But the lack of clear regulatory requirements for aquaculture in federal waters has all but prohibited aquaculture in the U.S. EEZ (Cicin-Sain et. al. 2005). The National Offshore Aquaculture Act of 2007, currently pending before Congress, would clarify federal regulatory requirements, thus allowing businesses and individuals to obtain a permit to operate in federal waters.

5. The study is concerned exclusively with the contained cultivation of fish, shellfish, and marine plants for food or other commercial products. In other words, the study presumes control and ownership of the product under cultivation by the farmer who must, therefore, have a property right to the waters in which he farms.

6. The study specifically excludes consideration of marine aquaculture for enhancement of wild fisheries, such as the stocking of shellfish or finfish (e.g. oysters, salmon, and redfish). Although stock enhancement and commercial aquaculture are two uses of aquaculture hatchery techniques and products, the economic structure of stock enhancement directed by public agencies is quite different from private, commercial marine farming.

**Background**

This is not the first time the United States has been urged to embrace marine aquaculture. In 1969, the Stratton Commission on Marine Science, Engineering and Resources published the seminal ocean policy report, *Our Nation and the Sea.*[2] That report had a profound influence over the next three decades on many marine activities, including aquaculture. It gave birth to NOAA as the nation's "Ocean's Agency," and was responsible for an immediate explosion of interest in sustainable uses of the sea and the protection of its ecosystems. It spawned ideas such as "farming the sea," and inspired the idea of a "Blue Revolution," comparing it to the "Green Revolution" in agriculture.

Perhaps the Stratton Commission recommendations were too ambitious. Marine aquaculture did not take off in the United States as it did elsewhere in the world. For many reasons, America's aquaculture industry, though vibrant and diverse, currently meets only 7.2% of our demand for seafood. Most of this is catfish. Marine aquaculture, largely in the form of oysters, clams, mussels, and salmon, supplies only about 1.5% of American seafood demand (NMFS 2007a). By contrast, in the past 30 years, aquaculture production in the rest of the world has expanded dramatically and now supplies almost half of world seafood demand (FAO 2006; Delgado et al. 2003). The upward trend is likely to continue. The United Nations Food and Agriculture Organization (FAO) estimated that an additional 40 million metric tons (mmt) of aquatic food will be required by 2030 over and above the 2005 worldwide consumption of 105.5

[2] http://www.lib.noaa.gov/edocs/stratton/

mmt (FAO 2006). FAO projects that most of this increase will be supplied by aquaculture. Few fisheries managers expect future increases in landings from commercial fisheries either in the United States or worldwide. So even if wild stocks are managed at sustainable levels, they will be unable to meet the increasing worldwide demand for seafood (Delgado et al. 2003; FAO 2006; The World Bank 2007).

Where have these developments left the United States? Globalization has profoundly affected U.S. seafood trade. We now import 80% of our seafood – 2.4 mmt or 5.4 billion pounds per year valued at $13.4 billion in 2006 (NMFS 2007a). These imports, about half from aquaculture, were paid for with weaker U.S. dollars against a background of ever-increasing global seafood demand. We also export about half of our wild catch to markets in Asia and elsewhere. This global trade has affected which species Americans eat. Modest growth in per capita U.S. seafood consumption is occurring almost exclusively among aquaculture-based species. Seafood consumption figures for 2006 show that, since 1992, salmon is up 128%, shrimp is up 76%, and catfish is up 6%. The consumption of tilapia, now in demand throughout the country, was not even measured in 1992. In contrast, U.S. consumption of many traditional U.S. fish has fallen since 1992—cod is down 53%, clams are down 15%, tuna is down 17%, and flatfish dropped off the top-10 list of most consumed species. Only scallop consumption is up, just over 13%, since 1992.

Aquaculture not only increases the current seafood supply, but also reduces supply uncertainty and provides consumers a consistent, affordable product available year-round. In addition to consumers, some segments of the U.S. economy have participated in and benefited from the worldwide growth in aquaculture. U.S. companies, investors, and farmers have participated in the global aquaculture industry by exporting technology, equipment, seedstock, services, investment, feed, and grain. A significant, but undocumented, portion of U.S. seafood imports are linked to these exports.

In addition to supply and production trends, health and nutritional concerns are likely to affect seafood consumption in the United States. Doctors and nutritionists are urging Americans to eat more seafood to improve their health (Mozaffarian and Rimm, 2006; Institute of Medicine, 2006). But if Americans increase their seafood consumption from one to two meals per week, where will this seafood come from? Right now, we have a choice – we can continue to import increasing amounts of seafood, most of it from aquaculture, or grow some of it here.

Offshore aquaculture is one of the new frontiers for marine aquaculture production that could supply this growing demand. The others include raising marine species in closed systems (tanks), in ponds with low salinity water, and with new or improved methods of culturing seafood in coastal areas. All of these methods have their opportunities and challenges. Aquaculture is being pushed to offshore and land-based locations in the United States and elsewhere due to competition for uses of coastal waters, high coastal land values, and poor water quality in many coastal areas due to runoff from human activities on land (Cicin-Sain et. al. 2005).

As for the offshore, the U.S. EEZ is huge. It covers 3.5 million square miles or 9 million $km^2$—20% more than U.S. lands—and spans Arctic to tropical marine habitats. Though not all

of the space in the EEZ can be used for aquaculture, conservative estimates show that less than 500 km² (less than 0.01% of the U.S. EEZ) would be enough to produce up to 600,000 metric tons or more of additional farmed seafood per year (Nash 2004). From the Atlantic and Caribbean to Alaska, the West Coast, Hawaii and the U.S. Trust Territories, this area spans a wide range of ocean conditions and habitats, making it feasible to farm an equally wide range of different aquatic species.

Culture of finfish, shellfish, and seaweeds in offshore waters is now technically feasible as shown by the dozens of commercial operations around the world using offshore aquaculture technologies. The United States is a leader in this type of aquaculture and in many related technologies. Currently, most of the emphasis worldwide is on the offshore farming of finfish because of market demand. However, shellfish, especially filter feeding bivalves such as mussels and scallops, can also be farmed offshore, as can seaweeds. Polyculture of finfish, shellfish, and algae in open ocean situations is also being pioneered in Canada, Spain, and elsewhere.

As in all new businesses, those who practice offshore aquaculture will learn by experience and will adapt through technical advances to the selective pressures of commerce and regulations. However, offshore aquaculture can only be established in the United States if operators are allowed to try it. Based on discussions at the 2007 National Marine Aquaculture Summit organized by NOAA, and discussions in other forums, investors and would-be investors in U.S. offshore aquaculture believe the biggest barriers to progress are the current lack of clear regulations to allow them access to needed marine waters and the certainty of operation,[3] Without clear rules:

- Entrepreneurs, fishermen, and others will not be allowed to try offshore aquaculture in the U.S. except in a few open ocean locations in state waters;
- U.S. investors and others will continue to set up offshore operations in other countries and may invest in other forms of aquaculture, such as land-based systems; and
- Americans may lose opportunities created by local production of seafood under U.S. laws.

U.S. investors are not waiting for the federal government to sort out its regulatory requirements. They are investing in offshore aquaculture in other areas, including the Caribbean and Latin America. Other countries such as Japan, Korea, Ireland, Norway, China, and Spain are working on offshore aquaculture technology and legal regimes (Lee and O'Bryen 2004; Ryan 2004).[4] In 2007, the European Union established an Offshore Aquaculture Technology Platform project with partners from 16 European Union countries and Norway.[5]

[3] See summary of National Marine Aquaculture Summit held in June 2007 in Washington, D.C. at http://aquaculture.noaa.gov.
[4] Also see conference program for Offshore Mariculture2006 held in Malta, Oct 11-13, 2006 at www.offshoremariculture.com/programme.cfm.
[5] See www.marine.ie/home/aboutus/newsroom/pressreleases/Offshore+Aquaculture+Workshop.htm and www.EATPnet.eu

## Opportunities and Challenges Considered in the Study

In examining the economic feasibility of U.S. offshore aquaculture, several authors highlight opportunities and challenges facing this new industry, including competitive advantages and disadvantages, economic viability and effects, competition between aquaculture and wild catch, and links between environmental and economic issues.

*Competitive Advantages and Disadvantages*

The United States presents offshore aquaculture producers with a number of advantages:

- A huge area in which to farm (the U.S. EEZ).
- Well-developed coastal infrastructure.
- A strong home market.
- Excellent fresh and frozen food distribution systems.
- High-value niche markets for fresh, whole, live, eco-label, or certified products.
- An educated workforce and people with excellent animal husbandry skills.
- U.S.-produced feed ingredients.
- Strong property laws.
- Leading offshore aquaculture equipment designers and manufacturers.
- Strong research and extension capabilities.

To put these advantages to good use, however, U.S. offshore aquaculture producers must overcome several disadvantages or constraints, including the following:

- High coastal land values for tourism and housing competing for space for shore-side hatchery, landing, and processing facilities.
- Complex regulations in state waters and lack of clear regulations for federal waters.
- Competition from other uses of coastal and offshore waters, such as unobstructed views, recreational boating and fishing, commercial fishing, and shipping.
- Competition from low-cost imported seafood.
- High labor costs for processing of seafood products.
- Rising costs of inputs such as energy and feed.
- Concerns by fishermen about competition from aquaculture.
- Concerns about environmental effects of aquaculture.
- Technological and transport (distance from shore) challenges.

In examining competitive advantages and constraints, several of the authors looked at how the experience of the poultry and catfish industries may apply to offshore aquaculture. The U.S. broiler industry, the world's largest producer and exporter of poultry meat, is competitive because it is technically advanced and highly efficient, and has ready access to home-grown feed and raw materials. The growth of the freshwater catfish industry in the United States, and the catfish industry's recent difficulties due to rising feed costs and competition from imported catfish substitutes, also provide a model and lessons learned for a domestic offshore aquaculture industry.

*Economic Viability and Economic Effects*

Several authors show that offshore aquaculture can be economically viable and examine the potential economic effects of offshore aquaculture. For example:

- Spreadsheet or business models for offshore aquaculture projects based on technology now in use in New Hampshire, Hawaii, and Puerto Rico show that culture of finfish and mussels can be profitable under certain cost and revenue conditions.[6]
- An input output model predicts that full- and part-time jobs created across all sectors per thousand metric tons of production per year will number 102 for mussels, 261 for salmon, 475 for cod, and 683 for scallops (meats), increasing employment numbers reflecting higher selling prices for these products.[7]

The authors also note that a variety of Americans may benefit from offshore aquaculture, including the following:

- Consumers will benefit by having access to affordable, locally and regionally produced, safe, and healthy seafood. The seafood supply, marketing, and food service industries, including supermarkets and restaurants, will have access to additional U.S. supplies of seafood, thereby reducing supply risks.
- Aquaculture and wild capture fisheries are part of a spectrum of seafood production techniques with many synergies. Boat owners (including fishermen) will be owner operators or hired by offshore operations. Seafood processing waste is used in making fish feed. The whole seafood supply chain, from boats to docks to processing plants to cold storage, benefits from having predictable and increased throughput from aquaculture. Marine aquaculture may help keep working waterfronts alive.
- Finite supplies of fish meal and oil for fish feed may limit the expansion of aquaculture and has raised questions about aquaculture's environmental sustainability unless alternatives can be found (FAO 2006). But not only does the United States have its own fish meal and oil menhaden and sardine fisheries, its researchers are among the world leaders in development of alternatives, such as feeds from soybeans, algae, yeasts, and other products. Aquaculture is a growing market for the nation's farmers, some of whose crops can be used in aquaculture feeds. The United Soybean Board's Soy in Aquaculture Program is an example.[8] There are also fishery wastes from the abundant fisheries of Alaska that could be made into fish meal and oil if there were incentive to do so.
- American companies have pioneered and are leaders in the design of offshore containment systems, hatcheries, and alternative feeds. Global markets for their products and services beckon. A strong home market will reinforce their position.
- Research at U.S. hatcheries directed at commercial marine aquaculture (fingerling and spat production for grow-out on land or in nearshore or offshore facilities) will

[6] In addition to the firm level analyses in this report, see Hoagland, et al. 2004; Jin et al. 2005; Kam, et al. 2003; Lipton and Kim, 2007; and Forster 1996.
[7] For another look at the potential economic impacts of offshore aquaculture in the Gulf of Mexico see Posadas, 2004.
[8] http://www.soyaqua.org

benefit not only commercial aquaculture, but the beneficiaries of stock enhancement practices. U.S. hatcheries grow finfish and shellfish to enhance recreational and commercial fishing stocks and to restore endangered species and habitat.

*Competition between Aquaculture and Wild Catch*

Several of the authors in this report consider the questions raised by competition and synergies with aquaculture.[9] The effect of increased U.S. aquaculture on U.S. wild caught fisheries will depend in part on whether new markets are created for increased U.S. aquaculture production, how fast and at what volumes new production comes to the market, whether new U.S. aquaculture production is a substitute for existing wild catch or imports, and whether U.S. fishermen participate in aquaculture production.

At the NOAA National Marine Aquaculture Summit in June 2007, and in other venues from the Gulf of Mexico to the Pacific Northwest, some commercial fishermen and others have expressed concern that aquaculture will hurt wild harvest in the United States. It is clear that aquaculture products, whether imported or domestic, compete with wild caught fisheries. They also compete with chicken, beef, and pork. Studies have also shown that global aquaculture production, notably of salmon and shrimp, contributed to reduced market prices for U.S. wild caught and farmed U.S. shrimp and for U.S. salmon caught from both wild and hatchery raised and released stocks (Knapp et al. 2007).

What is also clear – and often missing from the discussion of competition – is that competition will exist with or without domestic aquaculture. The marketplace is global and demand for seafood products is growing. The United States cannot meet consumer seafood demand through wild caught fishing activities alone. Seafood imports and other forms of protein, such as beef and chicken, already provide significant competition. Seafood business executives speaking at the National Marine Aquaculture Summit said that if seafood is not available from U.S. sources, their customers are demanding that they get it somewhere else (NMFS 2007b). The challenge therefore is to integrate aquaculture into domestic seafood production so that U.S. boat owners, fishermen, processors, and marketing companies can benefit directly.

*Environmental Issues*

As noted among the caveats, environmental concerns with regard to aquaculture are the subject of much debate and widely differing views, and the links between environment and economics are discussed by several of the authors. These authors and others note that competitive pressures, innovation, and efficient regulations are pushing aquaculture toward best management or sustainable practices. The awareness of environmental constraints and issues is timely, and even essential for the aquaculture industry for several reasons:

- Climate change and the quality of ocean resources may directly affect the growing environment and resources available to aquaculture.
- The aquaculture industry may have no choice but to move to more efficient practices as feed, clean water, and energy are likely to become scarce or more expensive (see Food and Agriculture Organization, 2006, and The World Bank, 2007).

[9] Also see Kristofersson and Anderson, 2005; Anderson, 2002; and Barnaby and Adams, 2002.

- Application of designs and management practices termed sustainable, smart design, green, or eco-effective are a way to address some environmental issues (McDonough and Braungart, 1998 and 2002).
- Companies following these designs are likely to have access to high-value niche markets and shelf space at supermarkets and restaurants that require eco-certification of seafood products.

**What Will Offshore Aquaculture Look Like in the United States?**

In this study, the authors present a framework for analyzing the economics of offshore aquaculture, preliminary results from economic models, and lessons learned from related sectors. Several of the authors show that offshore aquaculture can be economically viable under certain cost and revenue conditions. Viable operations will in turn create jobs from coastal communities to the country's farming heartland. The initial commercial finfish and mussels operations in open ocean locations in state waters have been successful enough to attract imitators and for additional investment to continue and expand their businesses. But their long-term success is by no means guaranteed. Current or future offshore aquaculture faces numerous economic and social challenges, as outlined in this report.

In my view, if offshore aquaculture proceeds in U.S. federal waters, various scales and regional approaches are likely to emerge. Right now, offshore aquaculture is still in its infancy. On top of that, U.S. aquaculture is diverse, and the regulatory structure for offshore aquaculture is still uncertain, so the technologies, species grown, cost structures, markets, and corporate structures of future offshore operations are still unknown. However, the pioneering offshore aquaculture ventures and research projects in U.S. state waters provide some indications of where the industry might be headed during the next decade.[10] For example:

- Cates International and Kona Blue Water Farms in Hawaii, and Snapperfarm in Puerto Rico, are pioneers of commercial open ocean finfish farming. They are selling product into high-value niche markets, they have demonstrated sufficiently positive results to attract additional investment from U.S. investors, and they are seeking to expand current operations. If the expansions are successful, these operations will be medium-sized commercial finfish operations, each producing about 500 to 1,000 metric tons of marine fish per year.

- A fisherman–owned and operated mussel farm off the coast of New Hampshire, Isle of Shoals Mussels, is using techniques pioneered by the University of New Hampshire's Atlantic Marine Aquaculture Center. The systems use floating submersible longlines anchored to the bottom (Fish Farming International, 2007). A similar private venture, Santa Barbara Mariculture, is located off the coast of California. Both operations harvested product and sold into commercial markets in 2007. The New Hampshire and Massachusetts Sea Grant programs also report interest from fishermen from Maine to Massachusetts who are considering this type of mussel farming.[11]

[10] For a review of U.S. projects see Barnaby 2006.
[11] Roland Barnaby and Richard Langan, 2008, personal communications.

- Great Bay Aquaculture in New Hampshire, one of the principal commercial suppliers of fingerlings to the marine aquaculture industry and research institutions, is producing species that are or could be used in offshore aquaculture, such as cobia and cod.

Offshore aquaculture is likely to undergo changes if it is permitted to move forward in the U.S. For example, if a regulatory framework is put in place, we might expect 10 years of experimentation and different approaches similar to the operations already in place in state waters. Total production is likely to be modest, with sales focused on niche markets (such as live, fresh, and certified markets). If one or more approaches are successful, rapid expansion could occur in the second decade. This has been the pattern in other aquaculture sectors around the world.

Niche market production will not supply the large quantities needed by supermarkets, restaurant chains, and the food service industry that depend on commodity products. While larger volumes have been supplied by many small operations in some parts of Asia, larger volume production in the United States is more likely to be supplied by vertically integrated operations similar to salmon, sea bass, and sea bream operations in Europe, Canada, and Chile.

The type of ownership and structure of small and large offshore operations in the United States also remains to be seen. All five of the small U.S. commercial offshore finfish and mussel operations were started by U.S. citizens active in commercial fishing and seafood businesses. Future participants in offshore aquaculture may include U.S. and foreign corporations and fishermen's cooperatives, as have been formed in Italy and Japan (Barnaby and Adams 2002) or similar combinations.

As noted in the 2007 *NOAA 10-Year Plan for Marine Aquaculture*, the United States stands at a critical juncture in the development and implementation of marine aquaculture in our nation. Future demands for healthy, safe, and local seafood will require many forms of aquaculture. Offshore aquaculture can be an important component of future domestic marine aquaculture if a regulatory framework is put in place and if offshore production proves to be financially sustainable. This report raises and discusses key questions about the economic viability and effects of offshore aquaculture. NOAA and others will continue to examine these issues and, as questions are raised, analyzed, and discussed, the answers will determine what U.S. marine aquaculture looks like 10 and 20 years from now.

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